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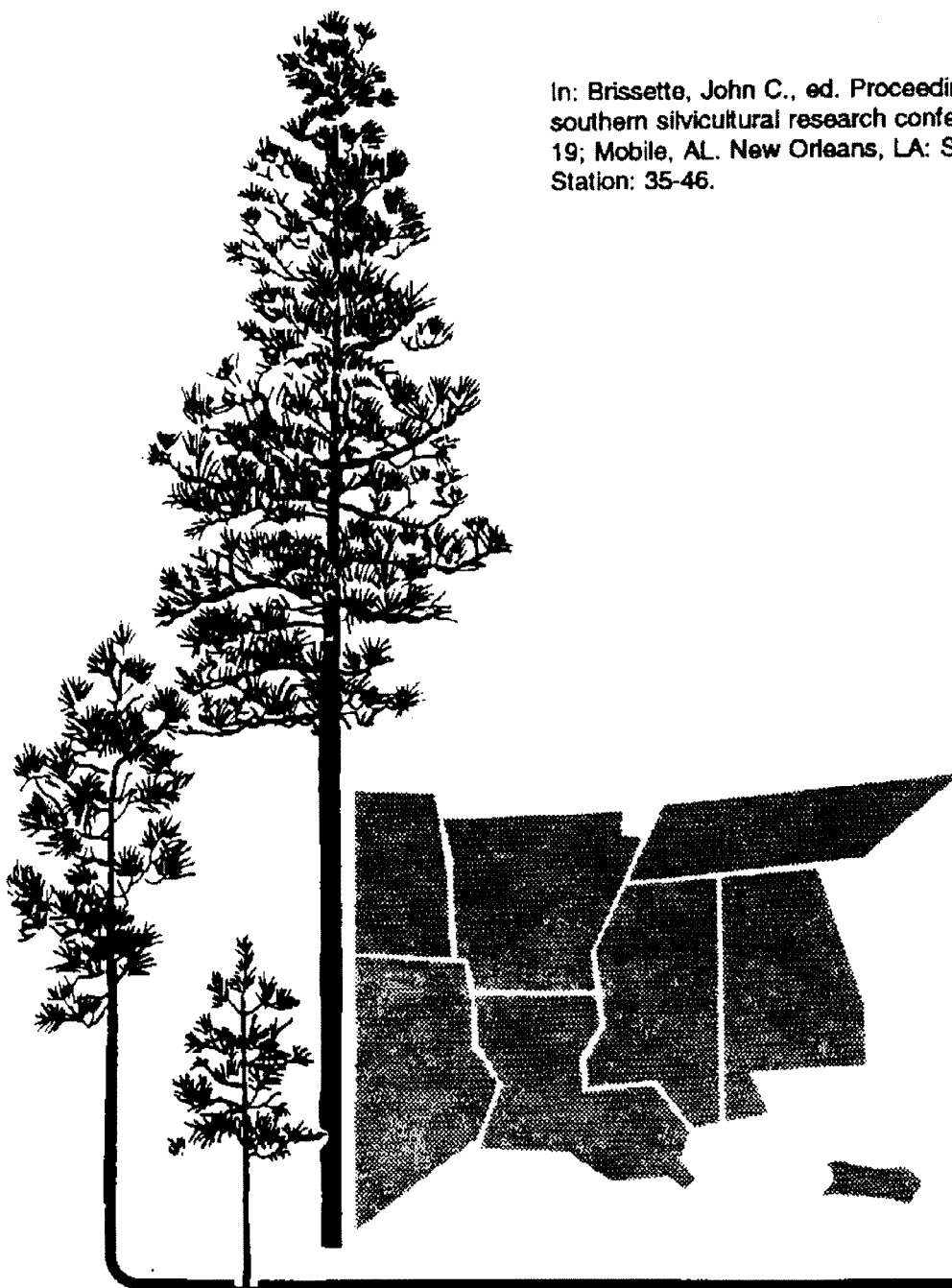
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## **FOREST FRAGMENTATION OF SOUTHERN U.S. BOTTOMLAND HARDWOODS**

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**Abstract.** The magnitude and character of forest fragmentation are evaluated for bottomland hardwoods in the Southern United States. Fragment size class is significantly associated with the frequency of bottomland hardwood species, stand size and ownership classes, and land use attributes. Differences in the frequency of indicators of multiple values (range, recreation, timber, water, and wildlife) are apparent. Two diverse hypotheses are suggested for further study: (1) fragmentation favors drier over wetter bottomland hardwood community types and (2) fragmentation shifts bottomland hardwood communities toward a younger successional stage and species typical of drier habitats. The first hypothesis suggests that drier stands are more vulnerable—and wetter stands less vulnerable—to fragmentation. The second hypothesis suggests that, on average, younger stands and dry-end bottomland species result from fragmentation of more mature and wetter stands. Data from recent South Central States forest surveys are used. Recent area changes suggest fragments are becoming smaller in selected regions.

### Introduction

Today's wetland ecosystems in the conterminous United States have been reduced to half of their original area, largely due to extensive land clearing for agriculture since pioneer days (Dahl 1990). Because forested wetlands often are the last areas to be developed, they are frequently portrayed as wild, unaltered natural environments. Yet many of the remaining forested wetlands may have altered hydrology and geomorphology. Species changes and multiple (e.g., range, recreation, timber, water, and wildlife) values have likely been altered as well.

Assessments of bottomland hardwood forests in the South Central States suggest that the rate of area decline has slowed in recent years (McWilliams and Rosson 1990). However, the rate belies the cumulative effects of landscape-scale change and past human disturbance on remaining bottomland hardwood area. This study initiates an exploration of cumulative effects from available data.

Forest fragmentation is the disruption of continuity in forest cover by water and nonforest land (i.e., agricultural land, and urban or built-up land, including roads). Fragmentation affects some faunal species distributions (Harris 1988), is a central issue in wildlife conservation (Wilcove 1990), and can have an effect on plant species distributions (Zacharias and Brandes 1990). Fragmentation also may affect multiple values of existing forested wetlands.

Historical data from permanent plots over a span of several lifetimes often are needed to test fragmentation effects on forest resources. Such data are rarely available. This report provides a synthesis of bottomland hardwood forest fragmentation. Information is from recent forest surveys of the South Central States (Alabama, Arkansas, Mississippi, east Oklahoma, Tennessee, and east Texas) by the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis Unit, Starkville, MS. Fragment size class is compared with the distribution of overstory tree species, forest proximity, and forest stand attributes.

The goal of the study is exploratory, namely to assess the significance of forest fragmentation for Southern United States forested wetlands. Specific objectives of the study are: (1) to evaluate the significance of forest fragmentation on bottomland hardwoods and associated multiple values and (2) to generate hypotheses for further study on how fragmentation affects bottomland hardwoods. Exploration can help focus on the direction needed in analytical techniques and auxiliary data acquisition to monitor multiple values of bottomland hardwood forests.

### Methods

As used in this report, a forest fragment is a contiguous land area at least 10 percent of which is covered with trees and unbroken by nonforest land.

<sup>1</sup> Paper presented at the Seventh Biennial Southern Silvicultural Research Conference, Mobile, AL, November 17-19, 1992.

<sup>2</sup> Research Forester, USDA Forest Service, Southern Forest Experiment Station, Starkville, MS.

A forest is a land area covered with trees, 1 acre or more in size and 120 feet (ft) or more in width. Fragment boundaries are nonforest land areas 120 ft or more in width. Pipelines and powerlines by themselves are not considered limiting. Fragments may be composed of different forest types and age classes. Fragments are inventoried in acreage classes as: 1 to 10, 11 to 50, 51 to 100, 101 to 500, 501 to 2,500, 2,501 to 5,000, and over 5,000 acres. Land cover interpretation is accomplished with National high-altitude color aerial photographs at 1:58,000 scale for those taken between 1986 and 1991, and 1:40,000 scale for color or 1:24,000 scale for black-and-white photographs for those taken between 1975 and 1985.

Approximately 1-acre sample plots are located systematically in each county at the intersection of perpendicular grid lines spaced at 3-mile intervals. Plots defined as timberland are surveyed for physical characteristics. Timberland is forest land not reserved from timber production and capable of producing industrial wood at a rate of 20 ft<sup>3</sup>/acre/year or more. Timberland comprises 98 percent of the forests of the region.<sup>3</sup> Fragment size, proximity from selected nonforest land, and evidence of human uses are sampled as part of the survey as well. Water proximity and sources seen on the plot are estimated from observations made during field visits.

Information on tree species composition and distribution by other attributes are derived from the most recent survey of timberland sample locations. Species composition is derived from a cluster of 10 points around each sample location (Forest Inventory and Analysis Research Work Unit 1989). Current tree sampling favors interior forest species, as clustered points are rotated toward the sample location when points are within 33 ft of the forest edge. At each point, live trees at least 5 inches in diameter at breast height (d.b.h.) are selected on variable-radius, 37.5 factor prism plots. On points stocked with fewer than two trees greater than 5 inches in d.b.h., the four most dominant trees are selected. Trees 1.0 to 4.9 inches in d.b.h. are measured on fixed, 7.1 ft radius plots centered on the first three points.

This report focuses on an assessment and recent changes in bottomland hardwoods associated with forest fragments of varying size. Bottomland

hardwoods are classified based on the stocking of tree species typical of wetland conditions (Anonymous 1972). For comparison purposes, the region is split into four physiographic boundaries: Mississippi Valley, East Gulf Coastal Plain, West Gulf Coastal Plain, and Interior Highlands (fig. 1).

Unless otherwise noted, the analysis consists of cross-tabulation of the presence and absence of an attribute on plots for each of seven fragment size classes. Only frequencies of an attribute's presence are listed. A Chi-square ( $\chi^2$ ) test of significant differences is performed to test the hypothesis of no association between an attribute and fragment size classes at the 0.05 probability level. Fragment size classes with expected presence or absence values < 5.0 are combined with the next nearest size class. If the hypothesis of no association is rejected, direction of the association is determined from the sign of the Pearson product-moment correlation (SAS Institute Inc. 1985). Correlations that include zero with one standard error are noted. Significant differences in attributes with numerical values are determined by comparing averages plus or minus 2 standard errors. Species' shade tolerance classes are derived from Burns and Honkala (1990). Species' soil and water associations are derived from Hupp (1992).

## Results

Total bottomland hardwood area, 15.7 million acres, varies by region and fragment size class and highlights the abundance of the intermediate (501 to 2,500 acres) fragment size classes (fig. 2). Regional differences are apparent, with the Interior Highlands having the least amount of bottomland hardwoods and a plurality in the smaller ( $\leq 500$  acres) fragment size classes (fig. 3).

Area change since the survey of a decade earlier represents a decline of 1.0 million acres. This decline varies significantly with fragment size class in the West Gulf Coastal Plain, Interior Highlands, and Mississippi Valley, but not in the East Gulf Coastal Plain (fig. 4). Area shifts are toward smaller fragment size classes.

Species richness is greatest for the 101 to 500 and 501 to 2,500 acre fragment size classes, a pattern also reflected within regions (fig. 5). However, species richness is sensitive to sample size.

<sup>3</sup> Rudis, Victor A.; Tansey, John B. Landscape-scale assessment of remote forests and black bear habitat from regional forest inventories. (1992 draft, 35 p.)

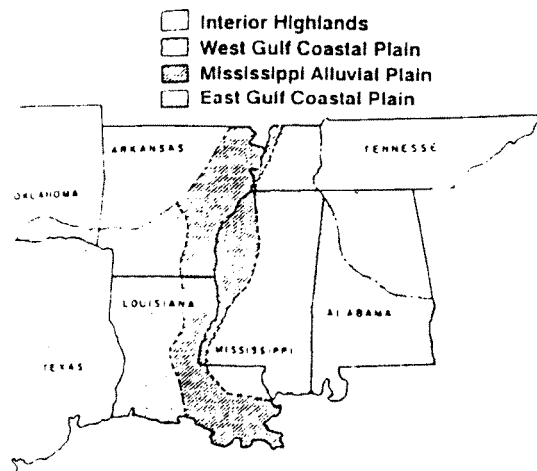


Figure 1. Physiographic regions of the South Central United States (adapted from Fennemann 1938).

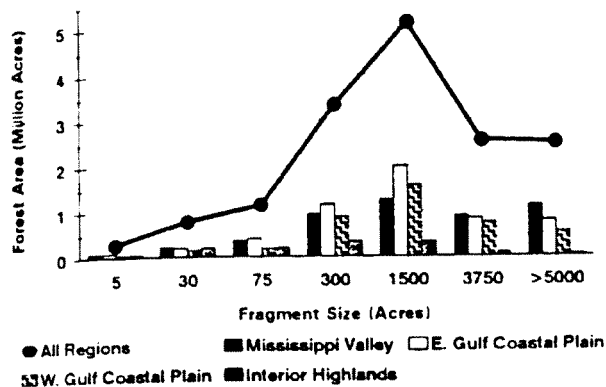


Figure 2. Relation between bottomland forest area and forest fragment size class in the South Central United States and by region, 1986-91.

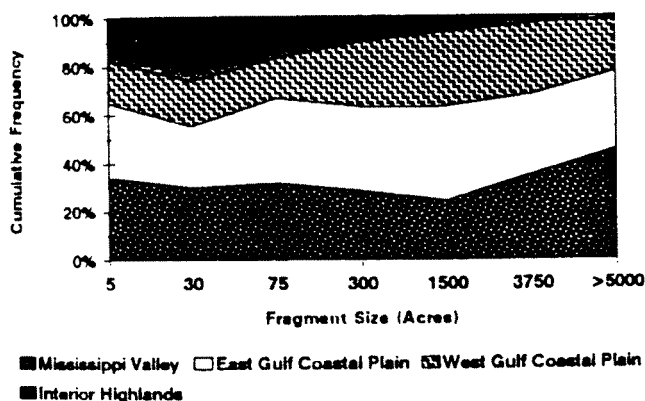
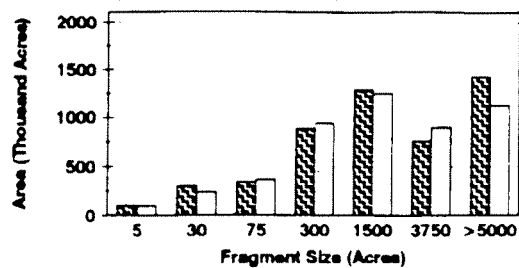


Figure 3. Frequency of bottomland hardwood forest area by fragment size class and region, South Central United States, 1986-91.

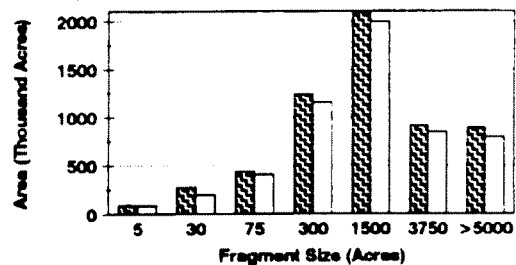
### Mississippi Valley

Chi-square = 53.0, Pearson  $r(x100) = -3.0$



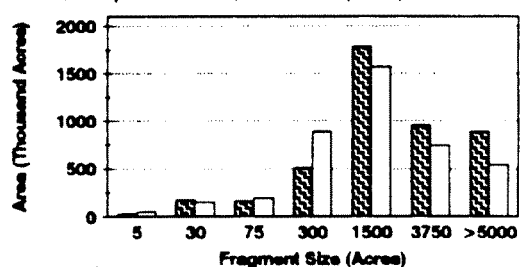
### East Gulf Coastal Plain

Chi-square = 8.8,  $P > .18$ , Pearson  $r$  not applicable



### West Gulf Coastal Plain

Chi-square = 228.2, Pearson  $r(x100) = -13.2$



### Interior Highlands

Chi-square = 43.3, Pearson  $r(x100) = -8.4$

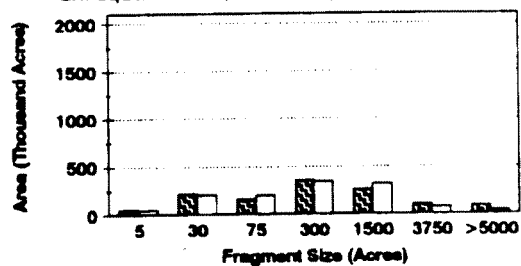


Figure 4. Area of bottomland hardwood forests by forest fragment size class, region, and survey period: 1975-84 (shaded) and 1986-91 (unshaded), South Central United States. Comparisons are made between forest area in each survey period and fragment size class.  $P(\text{Chi-square} > 43.0) < 0.001$ .

Statistical differences in average species richness are slight, except between the 1 to 10 acres and >5,000 acres, and the 11 to 5,000 acre fragment size classes (fig. 6).

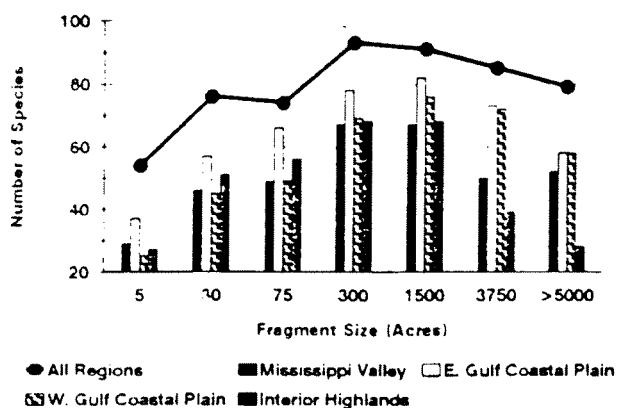


Figure 5. Relation between the number of species surveyed in bottomland hardwood forests and forest fragment size class in the South Central United States and by region, 1986-91. Sample size = 2,666 plots.

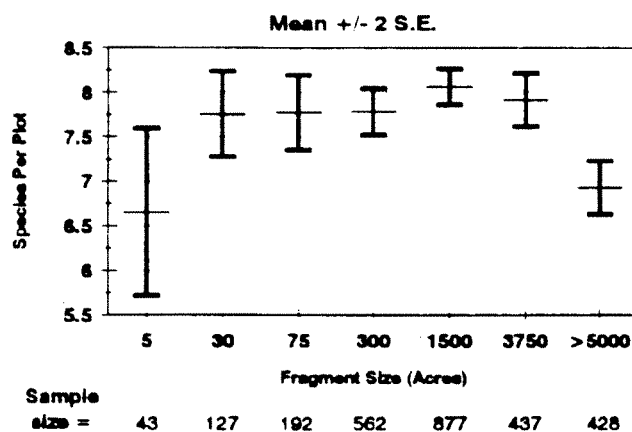


Figure 6. Average species per plot surveyed in bottomland hardwood forests by forest fragment size class, South Central United States, 1986-91. Listed also is sample size per fragment size class.

Significant frequency differences by fragment size class are apparent for several species (tables 1 and 2). Baldcypress (*Taxodium distichum* (L.) Rich.), overcup oak (*Quercus lyrata* Walt.) and others at the wetter end of the spectrum of bottomland hardwood tree species are more frequent in larger (>2,500 acres) fragments. Drier-end bottomland species such as winged elm (*Ulmus alata* Michx.) and early colonizers of recently disturbed stream channels such as river birch (*Betula nigra* L.) are more frequent in smaller fragments.

The majority of commercial tree species positively associated with fragment size class are shade tolerant species typical of stable soil and water flow and late successional or mature forests (table 1). The majority of commercial tree species negatively associated are shade intolerant species typical of unstable soil and water flow and early successional or pioneer forests (table 2).

Species with no significant association or insufficient sample size are listed in table 3. The few frequently occurring species with no significant association are intolerant of shade (e.g., willow oak *Quercus phellos* L.) or are typical of drier sites (e.g. post oak, *Quercus stellata* Wagh.). Cottonwood (*Populus deltoides* Bartr. ex Marsh.) is typical of disturbed stream channels but is not significantly associated with fragment size classes (table 3).

Forests associated with smaller fragments are more likely to be in private ownership, in sapling seedling or poletimber size class, and contain a higher percentage of rough and rotten trees. Forests associated with larger fragments are more likely to be in corporate or public ownership, to be sawtimber size class, and contain a higher percentage of growing stock trees (figs. 7a,b, and 8). Differences in the frequency of water sources seen when surveying plots are slight. Fragment size class is associated with water sources seen on the plot during field visits principally permanent swamps (fig. 9).

Proximity of forest fragments from nonforest land suggests that fragmentation is most closely associated with agricultural land use. Fences and roads are also associated. Urban land use is less important. Hunting club signs are significantly more frequent near large fragments, suggesting that these hold greater value for primitive-oriented recreation than smaller fragments. Smaller fragments are more accessible, an indicator of urban-oriented recreation value (table 4).

More frequently, a smaller fragment includes containers and other trash, an indicator of the increased potential to accumulate discarded materials. Discarded materials represent human intrusions that are disliked strongly by people with primitive-oriented recreational preferences (Rudis 1987). Evidence of livestock use, an index of agroforestry value, also is greater in smaller fragments. Artifacts positively associated with fragment size class include Spanish moss (*Tillandsia usneoides* L.), an indicator of unique and esthetically-valued habitats, and logging debris, an indicator of past timber production value (table 5).

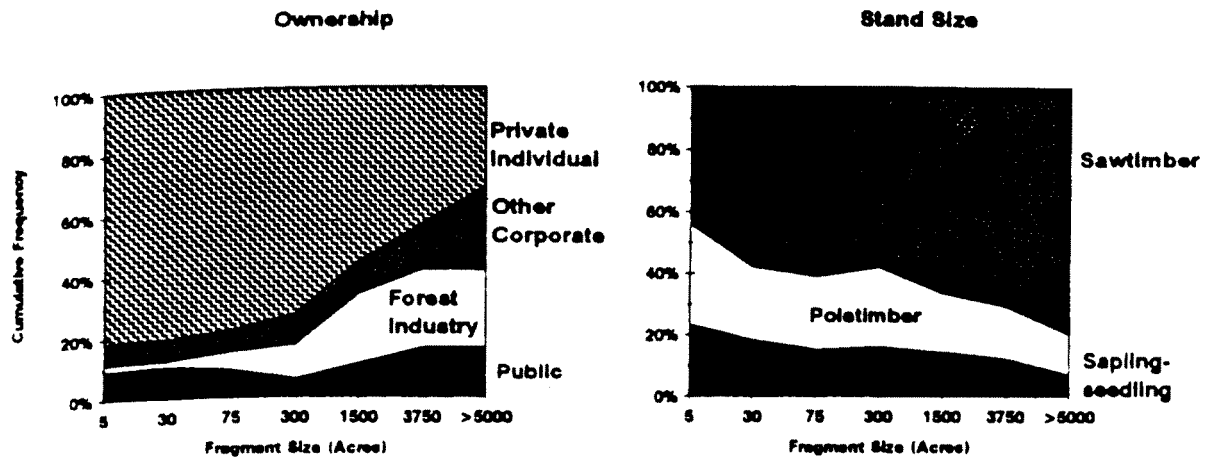


Figure 7. Frequency of bottomland hardwood forest area by fragment size class and (a) ownership class, (b) stand size class, South Central United States, 1986-91.

## Discussion And Conclusions

### Causes for Fragmentation

Agricultural development is significantly associated and is suggested as a primary cause for forest fragmentation of southern bottomland hardwoods. Fragmentation by urban influences likely plays a minor role in the South Central States. Agricultural development as a principal cause for hydric forest community fragmentation corroborates findings from a detailed examination of selected Southeastern United States river systems.<sup>4</sup> With additional study, differences in the regional distribution of fragment size classes and the documented shift toward smaller fragments from selected regions may suggest other, more localized, landscape-scale influences that favor fragmentation.

### Species Changes

Smaller fragments are more frequently composed of early successional or dry-end bottomland or upland species. Larger fragments have more late successional, mature, or wetter bottomland hardwood species. If an acceptable classification for old growth bottomland hardwoods is available, most old growth stands are likely to occur in larger fragments.

There are two diverse hypotheses. One is that fragmentation favors drier over wetter bottomland hardwood community types. On average, smaller

fragments represent drier subsets of bottomland community types; larger fragments represent wetter subsets.

If this hypothesis is true, then wetter habitats are less vulnerable--or more resistant--to fragmentation. An implication of this hypothesis is that drier bottomland hardwoods have the greatest potential for fragmentation. This hypothesis parallels that proposed by McWilliams and Rosson (1990); namely that drier bottomlands of the Southern Coastal Plain are more vulnerable to land clearing.

A second, alternative hypothesis is that fragmentation shifts bottomland hardwood communities toward a younger successional stage and species typical of drier habitats. On average, fragmentation is independent of the dryness or wetness of habitats. Rather fragmentation induces the establishment of pioneer species, widely-adaptable species, and those typical of unstable hydrology and geomorphology. Vegetation in smaller fragments may mature if left undisturbed, and hydrology and geomorphology may stabilize with time. However, short-term survival of flora and fauna of larger fragments with species typical of mature and wetter bottomland forests and stable hydrology and geomorphology are threatened.

<sup>4</sup> Wein, G.R.; Collins, B.S. Bottomland hardwood forest fragmentation on three southeastern rivers with different land use histories. Paper presented at the annual meeting of the Society of Wetland Ecologists; June 1992, New Orleans, LA. [1992 draft, 14 p.]

Table 1. Percent frequency among 2,666 plots by species and forest fragment size class, South Central United States bottomland hardwoods, 1986-91. [Significant positive association,  $P(\chi^2) < 0.05$ ].<sup>1</sup>

Species	Plots occupied	Fragment size (acres)							X <sup>2</sup>	Pearson r(x100)
		Class midpoint value								
		5	30	75	300	1500	3750	> 5000		
----- (percent) -----										
<i>Fraxinus pennsylvanica</i> Marsh.	38	37	34	37	36	34	42	47	24.0	8.3
<i>Acer rubrum</i> L.	32	21	17	24	32	34	33	36	25.1	5.6
<i>Celtis laevigata</i> Willd.	28	33	37	33	27	25	29	30	14.0	.6
<i>Quercus lyrata</i> Walt.	24	9	14	20	18	23	33	31	55.2	13.3
<i>Taxodium distichum</i> (L.) Rich.	22	12	16	14	17	17	26	43	141.8	21.3
<i>Carpinus caroliniana</i> Walt.	22	2	12	15	21	27	25	18	42.5	1.4
<i>Carya aquatica</i> (Michx. f.) Nutt.	16	9	17	17	14	14	21	20	18.0	6.6
<i>Salix</i> spp. L.	13	21	17	14	12	9	11	20	37.8	5.4
<i>Quercus nuttallii</i> Palmer	12	12	9	12	11	10	17	15	18.3	6.9
<i>Nyssa aquatica</i> L.	10	-	2	2	8	8	12	25	135.8	20.2
<i>Diospyros virginiana</i> L.	10	5	9	17	8	9	11	10	14.2	.9
<i>Quercus laurifolia</i> Michx.	8	7	4	4	6	9	8	9	13.3	4.8
<i>Fagus grandifolia</i> Ehrh.	7	2	2	3	6	9	9	4	28.9	.5
<i>Ilex opaca</i> Ait.	6	-	2	2	5	9	8	4	30.5	1.9
<i>Ulmus crassifolia</i> Nutt.	6	2	2	9	5	4	8	6	18.8	3.3
<i>Ostrya virginiana</i> (Mill.) K. Koch	5	-	2	4	4	7	7	3	18.2	.4
<i>Planera aquatica</i> J.F. Gmel.	4	2	4	3	3	4	4	8	14.6	6.3
<i>Pinus glabra</i> Walt.	3	-	1	1	2	4	3	2	13.1	1.6
Miscellaneous spp. <sup>2</sup>	4	2	5	2	3	3	4	7	12.7	5.5

<sup>1</sup> One standard error (Pearson  $r \times 100$ )  $\leq 2.0$ .

<sup>2</sup> Includes shrub species with stems  $\geq 5.0$  inches in d.b.h. and tree species rarely encountered in the region.

- = None among sampled trees.

Table 2. Percent frequency among 2,666 plots by species and forest fragment size class, South Central United States bottomland hardwoods, 1986-91. [Significant negative association,  $P(\chi^2) < 0.05$ ].<sup>1</sup>

Species	Plots occupied	Fragment size (acres)							X <sup>2</sup>	Pearson r(x100)
		Class midpoint value.								
		5	30	75	300	1500	3750	> 5000		
		----- (percent) -----								
<i>Liquidambar styraciflua</i> L.	54	44	50	52	57	59	52	44	32.6	-7.4
<i>Quercus nigra</i> L.	41	26	40	41	45	46	38	28	45.7	-9.6
<i>Ulmus americana</i> L.	27	47	35	33	28	27	24	23	19.7	-6.3
<i>Nyssa sylvatica</i> Marsh.	27	21	14	25	26	33	28	17	47.6	-4.2
<i>Carya</i> spp. Nutt.	22	12	22	25	20	25	22	16	20.8	-4.1
<i>Quercus falcata</i> var. <i>pagodifolia</i> Ell.	17	16	21	14	20	18	18	11	19.0	-5.5
<i>Ulmus alata</i> Michx.	17	12	28	27	18	18	12	1	51.1	-11.9
<i>Pinus taeda</i> L.	12	12	6	9	13	17	12	6	38.7	-5.5
<i>Platanus occidentalis</i> L.	12	23	22	16	12	11	10	13	22.1	-3.4
<i>Acer negundo</i> L.	11	16	24	11	11	9	10	13	29.4	-1.4
<i>Quercus alba</i> L.	11	5	10	10	10	13	12	5	21.7	-4.4
<i>Liriodendron tulipifera</i> L.	10	5	9	12	14	11	8	4	33.7	-9.7
<i>Magnolia virginiana</i> L.	9	2	6	7	11	12	8	4	32.1	-6.3
<i>Gleditsia triacanthos</i> L.	6	16	14	7	7	4	7	7	33.0	-1.1
<i>Carya illinoensis</i> (Wangenh.) K. Koch	6	12	14	5	6	5	5	5	22.2	-3.0
<i>Quercus falcata</i> Michx.	5	7	6	8	7	5	5	2	20.2	-7.5
<i>Betula nigra</i> L.	5	5	6	9	6	5	3	3	15.9	-7.0
<i>Morus rubra</i> L.	4	9	6	5	3	5	5	2	14.0	-2.2
<i>Quercus shumardii</i> Buckl.	4	5	9	6	4	4	2	1	25.8	-8.1
<i>Prunus serotina</i> Ehrh.	3	5	7	3	3	5	3	1	17.3	-5.5
<i>Celtis occidentalis</i> L.	3	5	7	6	3	3	2	2	15.0	-5.8
<i>Pinus elliotii</i> Engelm.	2	2	-	1	3	4	3	1	16.9	-1.7
<i>Maclura pomifera</i> (Raf.) Schneid.	1	5	3	4	2	1	1	X	19.8	-6.5
<i>Quercus velutina</i> Lam.	1	2	2	3	2	1	1	-	17.1	-6.7
<i>Pinus echinata</i> Mill.	1	-	-	1	2	1	1	-	6.2	-4.2

<sup>1</sup> One standard error (Pearson  $r \times 100$ )  $\leq 2.0$ .

X = Less than 0.5 percent.

- = None among sampled trees.



Table 3. Percent frequency among 2,666 plots by species and forest fragment size class, South Central United States bottomland hardwoods, 1986-91. [No significant association,  $P(\chi^2) \geq 0.05$ ].

Species	Plots occupied	Fragment size (acres)						
		Class midpoint value						
		5	30	75	300	1500	3750	> 5000
----- (percent) -----								
<i>Quercus phellos</i> L.	24	21	18	27	22	24	27	23
<i>Quercus michauxii</i> Nutt.	11	5	9	7	9	13	13	11
<i>Ulmus rubra</i> Muhl.	10	9	6	10	10	11	11	8
<i>Quercus stellata</i> Wangenh.	6	14	8	5	7	8	5	1
<i>Fraxinus americana</i> L.	6	2	8	9	6	6	4	4
<i>Populus deltoides</i> Bartr.								
ex Marsh. var. <i>deltoides</i>	5	2	7	6	6	5	5	6
<i>Crataegus</i> spp. L.	5	5	3	5	5	5	6	7
<i>Cornus florida</i> L.	5	2	3	3	5	6	5	3
<i>Nyssa sylvatica</i> var. <i>biflora</i>								
(Walt.) Sarg.	5	-	2	4	5	5	4	7
<i>Magnolia grandifolia</i> L.	2	-	2	2	2	4	2	1
<i>Gleditsia aquatica</i> Marsh.	2	2	2	2	2	3	3	2
<i>Acer saccharinum</i> L.	2	-	2	4	1	2	3	2
<i>Sassafras albidum</i> (Nutt.) Nees	2	-	2	1	2	2	1	1
<i>Persea borbonia</i> (L.) Spreng.	1	-	1	1	2	2	1	1
<i>Cercis canadensis</i> L.	1	-	1	2	2	2	1	X
<i>Quercus rubra</i> L.	1	-	2	3	2	1	1	X
<i>Prunus</i> spp. L.	1	-	1	1	-	2	1	1
<i>Acer barbatum</i> Michx.	1	-	-	-	-	2	1	1
<i>Oxydendrum arboreum</i> (L.) DC.	1	-	1	1	1	1	1	1
<i>Quercus palustris</i> Muenchh.	1	-	1	3	1	1	1	X
<i>Acer saccharum</i> Marsh.	1	-	2	1	X	1	1	X
<i>Sapium sebiferum</i> (L.) Roxb. <sup>1</sup>	1	5	2	2	X	1	X	X
<i>Juniperus virginiana</i> L.	1	-	1	1	2	1	1	-
<i>Juglans nigra</i> L.	1	5	3	3	X	1	X	1
<i>Vaccinium arboreum</i> Marsh.	1	-	1	1	2	1	X	X
<i>Quercus virginiana</i> Mill.	1	2	1	-	1	1	X	1
<i>Tilia americana</i> L.	1	-	2	1	1	1	1	X
<i>Quercus coccinea</i> Muenchh.	1	-	1	2	X	X	X	X
<i>Quercus bicolor</i> Willd.	X	-	1	1	X	X	1	X
<i>Magnolia acuminata</i> L.	X	-	-	1	1	X	1	X
<i>Quercus macrocarpa</i> Michx.	X	2	2	1	X	X	-	X
<i>Quercus muehlenbergii</i> Engelm.	X	-	1	2	1	X	1	-
<i>Quercus stellata</i>								
var. <i>paludosa</i> Sarg.	X	2	2	1	X	X	1	-
<i>Quercus prinus</i> L.	X	-	-	-	X	X	1	-
<i>Robinia pseudoacacia</i> L.	X	-	2	-	1	X	-	-
<i>Morus alba</i> L.	X	-	-	1	1	X	X	-
<i>Melia azedarach</i> L.	X	2	1	-	X	X	X	-
<i>Pinus palustris</i> Mill.	X	-	-	-	X	X	-	X
<i>Tilia heterophylla</i> Vent.	X	-	-	-	X	X	X	-
<i>Magnolia macrophylla</i> Michx.	X	-	-	-	X	-	1	X
<i>Catalpa</i> spp. Scop.	X	-	-	-	X	X	X	-

Table 3. Percent frequency among 2,666 plots by species and forest fragment size class, South Central United States bottomland hardwoods, 1986-91. [No significant association,  $P(X^2) \geq 0.05$ ]. Continued

Species	Plots occupied	Fragment size (acres)						
		Class midpoint value						
		5	30	75	300	1500	3750	>5000
----- (percent) -----								
<i>Quercus marilandica</i> Muenchh.	X	-	-	-	X	X	X	-
<i>Amelanchier</i> spp. Medic.	X	-	-	1	X	X	-	-
<i>Ulmus pumila</i> L.	X	-	1	1	X	-	X	-
<i>Quercus durandii</i> Buckl.	X	-	-	-	1	X	-	-
<i>Aesculus octandra</i> Marsh.	X	-	-	1	X	X	-	-
<i>Aesculus glabra</i> Willd.	X	-	-	-	-	X	-	X
<i>Aesculus</i> spp. (other than above)	X	2	-	1	-	X	-	-
<i>Ulmus serotina</i> Sarg.	X	-	-	-	-	X	-	X
<i>Chamaecyparis thyoides</i> (L.) B.S.P.	X	-	-	-	-	X	-	X
<i>Fraxinus profunda</i> (Bush) Bush	X	-	1	-	-	-	X	-
<i>Halesia carolina</i> L.	X	-	-	-	-	X	-	-
<i>Gymnocladus dioica</i> (L.) K. Koch	X	-	1	-	X	-	-	-
<i>Juglans cinerea</i> L.	X	-	-	-	-	-	-	X
<i>Malus</i> spp. Mill.	X	-	-	-	-	-	-	X
<i>Castanea dentata</i> (Marsh.) Borkh.	X	-	-	-	X	-	-	-
<i>Quercus incana</i> Bartr.	X	-	-	-	X	-	-	-
<i>Paulownia tomentosa</i> (Thunb.) Sieb. & Zucc. ex Steud. <sup>1</sup>	X	-	-	-	X	-	-	-
<i>Quercus laevis</i> Walt.	X	-	-	-	X	-	-	-
<i>Ailanthus altissima</i> (Mill.) Swingle	X	-	-	X	-	-	-	-
<i>Castanea pumila</i> Mill.	X	-	-	X	-	-	-	-
<i>Pinus serotina</i> Michx.	X	-	-	1	-	-	-	-
<i>Ulmus thomasi</i> Sarg.	X	-	-	1	-	-	-	-

<sup>1</sup> Identified as a category apart from "miscellaneous" only for Tennessee 1990 and Louisiana 1991 surveys.

X = Less than 0.5 percent.

- = None among sampled trees.

Table 4. Percent frequency among 1,853 plots by land use or cover proximity within 0.25 mile and by forest fragment size class. South Central United States bottomland hardwoods, 1986-90.<sup>1,2</sup>

Land use or cover	Plots occupied	Fragment size (acres)							X <sup>2</sup>	Pearson r(x100)
		Class midpoint value								
		5	30	75	300	1500	3750	> 5000		
----- (percent) -----										
Agricultural land $\geq 10$ acres	55	86	90	90	74	49	31	22	364.0	-41.3
Open water $\geq 0.125$ acre in size or $\geq 120$ feet wide	52	41	59	54	48	50	50	60	10.7	1
Gravel or dirt roads and no paved roads	49	69	54	56	51	51	42	37	29.2	-11.5
Fences	44	69	64	59	55	44	25	23	137.0	-26.5
Without roads	38	10	22	27	30	37	51	61	107.1	23.5
Paved roads	13	21	24	17	19	12	7	2	57.3	-16.8
Hunting restricted, hunting club signs	5	-	3	1	5	6	7	7	13.0	5.9
Urban or built-up land $\geq 10$ acres	2	3	11	4	3	2	X	X	33.6	-9.9

<sup>1</sup> Excludes Louisiana 1991—data has been collected but not yet compiled.

<sup>2</sup> Significance of association:  $P(X^2=29.2) < 0.001$ ;  $P(X^2=13.0) < 0.03$ . One standard error (Pearson  $r \times 100$ )  $\leq 2.3$ .

<sup>3</sup> Not applicable,  $P(X^2=10.7) > 0.09$ .

X = Less than 0.5 percent.

- = None observed.

Table 5. Percent frequency among 1,853 plots by artifacts seen on 1-acre plots and by forest fragment size class. South Central United States bottomland hardwoods, 1986-90.<sup>1,2</sup>

Artifact(s)	Plots occupied	Fragment size (acres)							X <sup>2</sup>	Pearson r(x100)
		Class midpoint value								
		5	30	75	300	1500	3750	>5000		
----- (percent) -----										
Beverage container(s)	33	38	47	39	31	31	35	32	13.6	-1.4
Other container(s), including trash (excluding beverage and food containers)	29	38	40	33	32	28	27	21	15.2	-7.6
Logging debris	22	14	22	14	19	25	25	22	14.0	4.8
Spanish moss ( <i>Tillandsia usneoides</i> L.)	12	7	1	6	11	11	14	23	42.5	13.1
Evidence of livestock use	12	31	26	24	15	10	6	2	86.2	-18.3
Food container(s)	10	31	23	15	8	9	7	8	42.1	-6.7
Building, foundation, or fence associated with a former or currently used homesite	5	10	8	3	6	5	3	2	12.1	-6.2

<sup>1</sup> Excludes Louisiana 1991—data has been collected but not yet compiled.

<sup>2</sup> Significance of association:  $P(X^2=42.1) < 0.001$ ,  $P(X^2=12.1) < 0.04$ . One standard error (Pearson  $r \times 100$ )  $\leq 2.3$ .

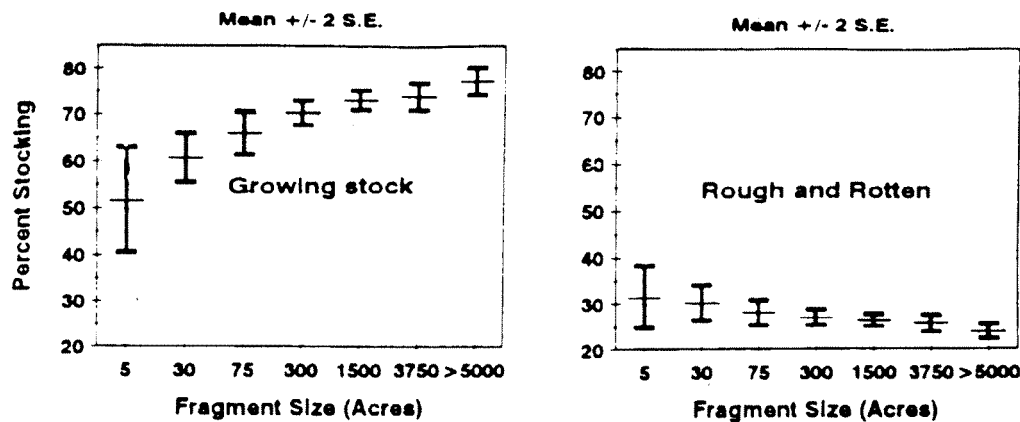


Figure 8. Average stocking of trees per plot surveyed in bottomland hardwood forests by forest fragment size class, South Central United States, 1986-91. Sample size = 2,666 plots.

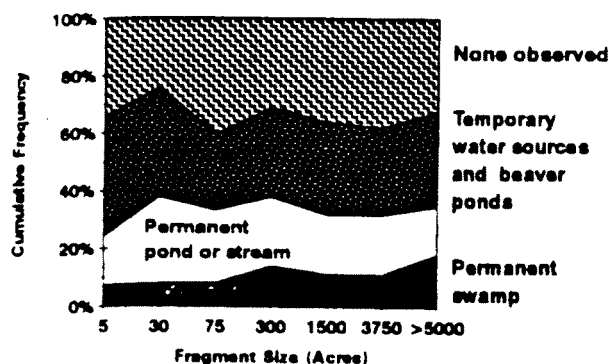


Figure 9. Frequency of bottomland hardwood forest area by fragment size class and water sources seen during field visits, South Central United States, 1986-90. (Excludes Louisiana 1991. Data has been collected but not yet compiled).

If true, the Interior Highlands is most vulnerable, as the region contains the least amount of bottomland hardwood area of all other regions. Most Interior Highlands area is in the smaller fragment classes. Connecting mature and wetter bottomland hardwoods with other forests along stream channels also could assist in maintaining habitats for fauna dependent on large forest fragments, e.g., black bear (*Ursus americanus*) (Rudis and Tansey 1992).

With existing data, analyses that may be useful in elucidating ecological community patterns include clustering of species' importance values and ordination along the fragment size class gradient. Combining existing data with understory plant surveys, especially surveys of shorter-lived herbaceous species, is more likely to reflect recent changes in microclimate implied by the second hypothesis.

Georeferenced information on soils, hydrology, landform, and elevation may be useful in clarifying hypotheses. Hydrology, geomorphology,

and vegetation succession have been used to explain species frequency patterns following recovery from stream channelization (Hupp 1992). Combining landform and direction with existing nonforest proximity measures is suggested to improve their utility as indicators of change to hydrology and geomorphology for bottomland hardwood communities. Another inventory technique practical currently only for watershed-scale inventories includes georeferencing of fragment area over time from available photo archives and plot records.

### Multiple Values

Smaller fragments are more frequently owned by individuals and are accessible by roads. Larger fragments are more frequently owned by corporations or public agencies and less accessible by roads. Smaller fragments are more likely to be associated with fences and contain human-associated litter than larger fragments. These influences increase the primitive-oriented recreation potential of larger fragments.

Regardless of the hypothesis, results indicate that fragmentation alters the multiple values of remaining bottomland hardwood communities. Associated value changes include reduced timber stocking of remaining trees in smaller fragments, increased livestock grazing, increased accessibility, and increased accumulation of discarded materials of human origin.

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